Similarly, with the sounds. Although the 103 vibration-sound and the 100 vibration-sound only coincide with theoretical accuracy once in a second, yet there is, three times per second, a coincidence so nearly accurate (within $\frac{1}{10300}$ of a second) that the practical effect in producing the beat is the same.

The rule, therefore, is practically right; but it should be qualified scientifically with the following addition:—*When the two vibration-numbers are prime to each other* (*i.e.* when they are not both divisible by any whole number) *the rule is not theoretically accurate, but if the times of vibration are very small* (*as they always are in practice*) *the error has no practical effect, and the rule consequently holds good.*

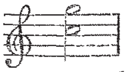
With the aid of this rule we can now tell the exact number of unison beats that will correspond to any amount by which the two notes are out of tune; and, *vice versâ*, we can tell the exact quantity by which two notes intended for unisons are out of tune by simply counting the number of beats they give. For example, suppose the A open string on the violin is played along with the fourth finger note (first position) on the third string, and that the latter is a little sharp, so as to give four beats per second, we know that the upper note will have four vibrations per second more than the other; and as at this point of the scale about twenty vibrations go to a semitone, we can tell that the upper note is about one-fifth of a semitone sharper than the lower one. To effect this, the fourth finger must be moved about one-twelfth of an inch nearer the nut than the former position, and this can be measured if any player think it worth the trouble, as a check to the calculation.

We may next inquire what effect on the ear is produced by changes in the rapidity of the beats. At first, when they are slow, no very unpleasant sensation is perceived, but as they become faster they give a sensation of roughness which is disagreeable in a marked degree. With a further increase of rapidity the effect becomes again less unpleasant, until it arrives at the slight tremulousness already mentioned in the *voix celeste* and *vox humana* stops, and which, as it is purposely produced, may be supposed to be rather agreeable than otherwise.

If we carry the error farther, the beats become so fast that the ear ceases to be able to appreciate them, and the beating effect entirely disappears.

Helmholtz, who has paid much attention to this subject, and who has founded on this property of beats some important musical speculations, is of opinion that the disagreeable effect increases gradually until the beats arrive at about thirty per second, where the harshness is at a maximum; that then the unpleasantness lessens as they grow faster, until, at about 100, or something more, per second, the beating effect disappears. Hence he calls from O to this point *beating distance* for any two notes near each other.

For example, if starting from the treble C, 512 vibrations per second, we sharpen the note to D♭, 546 vibrations, and then sound this with the original C, we shall get $546 - 512 = 34$ beats per second, which gives a very harsh effect. If we go on to D, 576 vibrations, we shall get, for the interval C to D, $576 - 512 = 64$ beats per second, which is less harsh; and if we go on to C with E♭, we shall have $614 - 512 = 102$ beats, which is hardly perceptible. For C to E, a major third, we have $640 - 512 = 128$ beats, and no one can assert that this interval, when in tune, has anything harsh or disagreeable about it.

A curious question has existed as to what becomes of the beats when they thus vanish. Are they entirely annihilated? or do they in their more rapid shape produce any other sensible effect of any kind? To explain the answer that was, by early writers, given to this question, one must mention a new phenomenon which occurs in connection with double sounds, namely, what is called the "grave harmonic." When two notes are sounded together they give rise to a third tone, of a fainter strength, and generally lower than both. Examples of this are usually taken from concords: thus, if the following two notes  are sounded on an organ, a violin, or any instrument of sustained sounds, and are perfectly in tune, the ear will, with attentive listening, hear a faint third sound resulting therefrom, which will be an octave below the lowest note of the concord, thus . If, instead of the fifth, the major third  be sounded, in like manner the "grave harmonic" will be an octave lower than before, namely, . This phenomenon was discovered by Tartini, the eminent violinist, and is often on this account called the "Tartini harmonic."

Now it happens that the number of vibrations of Tartini's harmonic, for any two given notes, is exactly the same as the number of the unison beats for the same notes, as hereinbefore described: and hence the idea arose that when the beats became so rapid as to lose their beating character, they gave rise to the grave harmonic; the explanation naturally presenting itself, that a beat recurring regularly with the proper rapidity would produce on the ear the effect of a musical sound. Dr. Young was the first to publish this explanation: he says ("Experiments and Inquiries respecting Sound and Light," sec. xi.), "The greater the difference in the pitch of the two sounds, the more rapid the beats, till at last they communicate the idea of a continued sound, and this is the fundamental harmonic described by Tartini."

Young's theory has been generally accepted until within the few last years, and in consequence the kind of beat we have been describing has been called "Tartini's beat." Helmholtz has lately thrown doubt on the correctness of Young's explanation, but the analogy of the numbers may warrant us in retaining the name, as distinguishing this beat from others which we will now proceed to describe.

(*To be continued.*)

UNITED STATES NATIONAL ACADEMY OF SCIENCES.

THE half-yearly meeting of the National Academy of Sciences was held at Philadelphia, Nov. 2, 3, and 4, 1875.

Prof. Joseph Henry has for several years been conducting the researches of the U.S. Lighthouse Board in respect to Fog Signals and the Transmission of Sound. While these experiments are not yet completed, the results up to the present time give the following indications:—The echo of sound passing over the ocean is more probably due to reflection from the surface of the waves than from the air; sound coming against the wind can certainly be heard at an elevation from a greater distance than at the sea level; with the velocity of the wind at about five miles an hour, sound was heard five times further with the wind than against it; sound is heard furthest with a moderate wind; with a strong wind it is not heard so far as in still air.

Prof. Joseph Le Conte, of California, contributed the results of his observations on mountain ranges of the Pacific coast. The author's theory is that the mountain chains in question were formed wholly by a yielding of the crust of the earth, along given lines, to horizontal pressure; not, however, resulting in a convex arch filled and sustained by liquid beneath, but by a mashing together of the whole crust, producing close folds and a swelling upwards of the squeezed mass. Prof. Le Conte went on foot through a cut made by the Central Pacific railroad from near St Francisco Bay eastward, a distance of 30 miles through the Coast

range, which consists of two sub-ranges wholly of crumbled strata. The average angles of dip are from 65° to 70°. The following estimates are made :—The folded strata are of 2½ to 3 times the length of a horizontal line drawn beneath them; *i.e.* 15 to 18 miles of sea bottom have been crushed into 6 miles, the surplus swelling upward. Numerous flattened clay pellets, chiefly ellipsoids or disks, and similarly flattened nodules of sandstone, furnished means of estimating the horizontal and vertical pressures to which the mass has been subjected. The mathematical formula employed was detailed. It was found that 2½ to 3 parts had been crushed into one horizontally, and every foot of vertical thickness had been thereby swelled up 2½ or 3 feet.

Major J. W. Powell of Washington has spent many years in scientific exploration of the cañons of Colorado latterly under the auspices of the Smithsonian Institution. He regards the geology of the Colorado region as so different from any other, that a new system will have to be devised to meet it. Major Powell offered the outlines of a new system for the details of this region, proposing to retain as far as possible the names that mark the labours of previous explorers in the field; and to give in addition geographical names as a provision expedient till the full order of the strata should be determined. The plateau region drained by the Colorado River of the West was more particularly under review in the essay before the Academy. Springing from the plateaus are single mountains, short ranges, and volcanic cones disposed in groups; the affluents of the river have their source in high mountains on the edge of the drainage basin. The river and its chief tributaries differ from other great rivers in the absence of considerable valleys along their course, at least north of 35° latitude. The streams run in deep cañons, and these, with other topographic features, separate the plateaus. This is part of the whole region of the United States west of the 100th meridian, which is distinguished by being everywhere of great altitude, with the trifling exceptions of a strip on the Pacific coast and some valleys of the larger streams. The rivers descend so rapidly that they are of little service for navigation; the valleys are exceedingly narrow; the table-lands and mountains are treeless, arid, and almost desolate. Bare rocks rarely masked by any soil give character to the "Rocky Mountain" region. Here there is everywhere an open book to the geologist, as the formations can be clearly traced, and the sections given by cañons display in regular succession the strata of palæozoic, mesozoic, and cainozoic eras, a total depth of 60,000 feet being thus revealed. The characteristics of the formations of this region were discussed at considerable length. As an instance of the irregularities of strata, the observations on lignite may be cited. It is frequently found through a horizon of 11,500 feet, in beds of varying thickness, distributed all the way from the lower Cretaceous up through three divisions of the Tertiary; but no particular bed of lignite is persistent over a large area. In one instance—the Rock Springs group—eleven beds of lignite were found, varying from 10 inches to 4 feet in thickness; but three miles away, careful observation showed all these beds represented by carbonaceous shales. In places separated by only a distance of a few miles, the succession of lignites is found to differ materially; they appear in general to have been formed in small irregular basins.

One of the most interesting papers read at the meeting was that of Prof. Raphael Pumpelly, of Newburgh, N.Y., on the Influence of Marine Life and Currents on the formation of Metalliferous Deposits. Beginning with the list of chemical elements which are found in the sea—now numbering 29 and likely to be largely increased—the author gave disinctive particulars as to the proportions of these substances, and the material in which they are found, whether sea-water, marine organisms, or structures that are products of marine life. All elements which compose the land are ultimately carried to the sea. The cycles through which different substances pass in their progress from land to sea, and thence again to the material of land, were traced in the cases of carbonic acid, lime, phosphoric acid, fluorine, and sulphur. As to the first of these, the sea is charged with nine per cent. of CO_2, the charge varying with the surface condition of the water and the immediate atmospheric conditions. The activity of the wave surface aids the escape of surplus carbonic acid into the air. Plant life in the sea as on land effects the decomposition of CO_2, using the carbon to build vegetable structure and freeing the oxygen to sustain marine vegetable life. But the carbon that is withdrawn to form coal, owing to its insoluble character, has been practically abstracted from this circulation. The ultimate result, the author thinks, would have been the decay of all life on the planet, for the want of the carbon thus locked up. Hence the work of man in mining and burning coal restores the balance of this circulation, by bringing the carbon into a condition in which it can be dissolved by moisture and enter into plant life through the leaves.

In describing the cycle of lime, Mohr's theory was alluded to. Sulphate of lime, decomposed by plants, supplies sulphur towards forming albumen by combining with carbon and ammonia, the oxygen being set free; carbonate of lime may perform a simpler operation in the plant, leaving behind the carbon and lime while liberating oxygen. The hydro-carbons are afterwards oxidized in the respiration of animals that feed upon the plants, and secrete structures of limestone.

Phosphoric acid and fluorine have slight chemical affinity, yet they are continually found associated in mineral deposits. Phosphate of lime and fluoride of calcium offer nearly equal resistance to solution by atmospheric and aqueous agencies. The first is a constant constituent of marine plants; both are found in the lower marine animals, and by their means are presumably brought together again in rock formation. Land plants and animals take a frequent part in this circulation. Disintegrated rocks form soil-supporting vegetation afterwards eaten by animals, whose digestive processes bring the substances in question into the more soluble states, in which they are most readily carried to the ocean.

The sea contains much dead organic matter, and in decomposition the sulphur of the sulphates and of the albumen plays an important part. As to the sulphates, the direct process of their decomposition in decaying organisms may be stated thus:—The carbon of the organic substance takes the oxygen from sulphuric acid and its base, giving a sulphide of the base and free carbonic acid; water and carbonic acid decompose the sulphide again, giving sulphuretted hydrogen and a carbonate. Oxidation of the sulphuretted hydrogen gives sulphuric acid, which in time, uniting with lime, completes the circuit of sulphur. On land the processes are far more intricate. It is probable that in the circuit of sulphur in marine organisms is to be found the key to their powers of eliminating from sea-water the heavier metals. The habitat of marine plants is determined by ocean currents, the growth and development being dependent upon freedom from such disturbance. Animal life follows vegetable. The accumulation of organic existence at certain localities in the ocean—as for instance the sargossa—determines there, in the process of its decay, the position of the material of rock formations, including the heavy metals which have been thus eliminated from their dispersion in sea-water. A thorough and minute chemical analysis of the earth brought up by the soundings of the *Challenger* and the *Tuscarora*, would be apt to throw light on some of the details of these problems.

The "Difference Engine," a calculating machine devised by Mr. George B. Grant, and now in course of construction for the University of Pennsylvania, was described by Prof. Fairman Rogers. The frame of the machine is 8 feet by 4 feet. To this frame are attached, though removable at will, 100 similar parts or elements, each of which is a small adding machine, representing a single decimal place during operation. When these elements are combined in groups, each group represents a certain difference of numbers, such as by consecutive additions to a starting number gives the required mathematical table or series. The difference thus added may be constant or variable. A table of squares is made by adding two differences, one constant, the other variable; cubes add three differences of which only one is constant. Logarithms are obtained similarly, though the operation is more complex. In this machine certain groups of elements are set to constant differences, and transfer their products in figures to other groups, which in turn transfer their variable values to groups above them. Babbage's machine was more costly, and Scheutz's more complicated than this; its chief advantages are: interchangeableness and ease of grouping of the elements, a constant introduced by simple apparatus in each element; an improved method by which the figure produced by any element is sent to the corresponding element in a higher group, and greatly improved arrangements for the operation of "carrying." The main figure-wheel of each element is moved forward by a carrier, which is released at the proper point by an inclined edge that takes it out of the way of the wheel. When a carriage is to be made, as for instance, if the wheel be at 8 and 3 be added, making 11, the next wheel standing at 0, which must be turned to 1, is so contrived that at the proper moment its inclined edge is slipped one tooth forward, and the carrier moves that wheel one step further than it otherwise would. This principle is so extended to successive carriages that if a long row

of nines is up, and unity be added on the wheel on the right, all the nines are at once replaced by zeros and one is added to the figure on their left. The machine presents a *cliché* of figures, the basis for a stereotype plate; it will calculate and print a table to ten decimal places at the rate of about forty turns per minute. A two-horse power engine will be required to drive it to its full capacity.

An arithmometer, or multiplying machine, devised by Mr. Grant, was also shown with, for comparison, those of Thomas de Colmar and Baldwin, it being adapted to the same purposes as those, but constructed on the principle of the difference engine.

Prof. R. E. Rogers gave some facts of interest respecting the silver mines known as the Comstock Lode. In the deeper drifts the temperature is much higher than can be explained by the usual hypothesis of interior heat; it frequently reaches 150° F. Water trickling from the roofs of these drifts is so hot as to be almost scalding; workmen have to be protected from it by iron screens. An application of ice-water to the head at intervals is found necessary to the support of life. The heat is due to chemical action, principally to the decomposition of sulphide of silver deposits which takes place when water containing chloride of sodium reaches them. There is some saline material in the ore. It is a singular fact that while there appears to be no trace of copper in the ore, the washing from the quicksilver mills, which runs into a pond and there evaporates, leaves a deposit which is only 300 fine instead of 700, all the rest being copper. To extract the silver, this deposit is put into a cap-like receptacle of felt, and hot quicksilver is turned upon it, which strains through, and carries with it the copper and gold, leaving the silver. The next process is to separate the gold from the copper in the drippings. To effect this the combined substance is heated to fusion and allowed to cool, when the two metals segregate, and the gold cracks off the copper. Before the discovery of this process the "tailings" of the mills had no value; now they prove of considerable worth.

Prof. J. Lawrence Smith has been studying a crystalline product obtained from the graphite of meteoric iron, that proves soluble in ether and crystallises in acicular form. Wöhler and Roscoe have announced the discovery of a similar substance in carbonaceous meteorites. Prof. Smith finds it in carbon nodules in the very centre of large masses of meteoric iron. Wöhler and Roscoe regard it as a hydro-carbon; Prof. Smith gives reasons for considering it a sulpho-hydro-carbon.

In another communication Prof. J. Lawrence Smith described a pendulum designed to meet the wants of a cheap and efficient compensating arrangement for common clocks. Prof. Smith has taken advantage of the great expansibility of vulcanite under changes of temperature. His experiments, in common with those of others, prove that its coefficient of expansion is about that of mercury, between 0° and 212°. In applying this simple form of compensating pendulum to clocks, he states that it need not add more than twenty or thirty cents to the cost of the pendulum ordinarily in use. He has constructed one with more perfect means of adjustment, yet very simple in character, which he thinks can be attached to regulators and astronomical clocks. Prof. Smith is now engaged in investigating any possible change in the materials used that may interfere with the permanency of this instrument; from the nature of the subject it will take some time to arrive at the necessary results. In these experiments he is assisted by a very competent associate.

The following were the papers presented at the session, in addition to those already mentioned:—Contributions to Meteorology, by Prof. Elias Loomis; Exposition of several peculiar Astronomical Phenomena, by Prof. Stephen Alexander; Confirmation of same author's Theory of the Zodiacal Light, by the same; Composition of Schorlomite, by Prof. George A. Koenig; Modern System of Chemical Terminology, by Prof. R. E. Rogers; Steam Geysers of California, by the same; the Annular Nebula in Lyra, by Prof. Edward S. Holden. Prof. C. E. Dutton's paper on certain Igneous Rocks of Southern Utah was read by title only.

NOTES

Prof. Hildebrand Hildebrandsson has published in the "Transactions" of the Royal Society of Sciences at Upsal, a clear and interesting account of a tornado which occurred near Hallsberg, in the province of Nerike, Sweden, on the 18th August, 1875. From the full details he gives it is evident that it closely resembled the tornadoes which have been described by the American meteorologists and the well-known tornado of Chatenay of 18th June, 1839, described by Peltier. Upwards of 1,000 large trees (*Pinus abies*), covering a space 1,000 feet in length by 500 feet in breadth, were totally destroyed, the greater number being torn up by the roots, whilst those about the margins of the path of the tornado were snapped across. On emerging from the forest, where its course had been directed to N.N.E., it turned in the direction of N.E., uprooting trees, overturning solid buildings, and carrying the *débris* of the ruins, in some cases, many miles from the scene of destruction. From the positions of objects thrown down, which are shown on a map, Dr. Hildebrandsson points out that in this instance the destructive force was compounded of two forces, one being directed towards the centre of the tornado and the other in the line of its course. The true theory of these terrible phenomena can only be arrived at by such carefully observed and collated facts as Dr. Hildebrandsson here presents us with; and much light would be thrown on this difficult question if barometric and thermometric observations were made within and near the district swept by the tornado.

Yesterday's *Standard* contains a letter from the *Challenger* correspondent of the paper, dated Valparaiso, Nov. 19. Honolulu was left on August 11 and a call made at Hilo (Hawaii), when the crater of Kilauea was visited. On the 19th the *Challenger* left and made for Tahiti, soundings and dredgings being carried on by the way, the average depth being 2,800 fathoms, with a bottom of red clay. Oxide of manganese was brought up in large quantities, and "many things of great interest to the naturalist." Several excursions were made on the Island of Tahiti, and every opportunity was made use of to get acquainted with the productions, soil, climate, and inhabitants. Sail was again made on Oct. 2, and Juan Fernandez reached on Nov. 13, the average depth of the section being 2,160 fathoms. Hill and dale were tramped over by the naturalists and others during the two days' stay, and numerous specimens of birds and plants obtained. Valparaiso was reached on the 19th.

Part II. of the first volume of the new series of the "Transactions" of the Linnean Society, just published, contains a paper by Dr. J. D. Macdonald, on the external anatomy of *Tanais vittatris*, occurring with *Limnoria* and *Chelura terebrans* in excavated pier-wood, and another by Dr. M'Intosh, on *Valencinia armandi*, a new Nemertean. The first part contains Mr. Parker's memoir on the skull of the woodpeckers, one by the late Dr. R. v. Willemoes-Suhm on some Atlantic Crustacea from the *Challenger* Expedition, and one by Dr. Allman on the structure and systematic position of *Stephanoscyphus mirabilis*, the type of a new order of Hydrozoa.

Some living specimens of the gigantic Tortoises of the Galapagos Islands, which were on their way to this country in H.M.S. *Repulse*, were lost, we regret to say, in a gale which did some damage to the ship and caused the death of two of the crew.

A new journal, *The Scientific Monthly*, devoted to the natural and kindred sciences, has been quite recently started at Toledo, Ohio, Mr. E. H. Fitch being the editor.

Messrs. H. Holt and Co., New York, will publish during the month a work entitled "Life Histories of Animals, including Man," by Mr. A. S. Packard, jun. This work having appeared in parts in the *American Naturalist*, we can most certainly vouch for its excellence.

We regret to have to announce the death of Mr. S. T. Davenport, well-known as an active and energetic officer of the Society of Arts. Mr. Davenport's connection with the Society had lasted for thirty-three years, and it was in great part to his unceasing and zealous efforts that the present prosperity of the